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Abstract

BACKGROUND: Various elderly case management projects have been implemented in Belgium. This type of long-term health care intervention involves contextual factors and human interactions. These underlying complex mechanisms can be usefully informed with field experts' knowledge, which are hard to make explicit. However, computer simulation has been suggested as one possible method of overcoming the difficulty of articulating such elicited qualitative views. METHODS: A simulation model of case management was designed using an agent-based methodology, based on the initial qualitative research material. Variables and rules of interaction were formulated into a simple conceptual framework. This model has been implemented and was used as a support for a structured discussion with experts in case management. RESULTS: The rigorous formulation provided by the agent-based methodology clarified the descriptions of the interventions and the problems encountered regarding: the diverse network top...

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Expert knowledge elicitation using computer simulation: the organization of frail elderly case management as an illustration

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agent-based modelling, case management, complexity, computer simulation, health care organization, knowledge

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Abstract

Background Various elderly case management projects have been implemented in Belgium. This type of long-term health care intervention involves contextual factors and human interactions. These underlying complex mechanisms can be usefully informed with field experts' knowledge, which are hard to make explicit. However, computer simulation has been suggested as one possible method of overcoming the difficulty of articulating such elicited qualitative views.
Methods A simulation model of case management was designed using an agent-based methodology, based on the initial qualitative research material. Variables and rules of interaction were formulated into a simple conceptual framework. This model has been implemented and was used as a support for a structured discussion with experts in case management.
Results The rigorous formulation provided by the agent-based methodology clarified the descriptions of the interventions and the problems encountered regarding:
1 the diverse network topologies of health care actors in the project;
2 the adaptation time required by the intervention;
3 the communication between the health care actors;
4 the institutional context;
5 the organization of the care; and
6 the role of the case manager and his or hers personal ability to interpret the informal demands of the frail older person.
Conclusion The simulation model should be seen primarily as a tool for thinking and learning. A number of insights were gained as part of a valuable cognitive process. Computer simulation supporting field experts' elicitation can lead to better-informed decisions in the organization of complex health care interventions.

Introduction

Case management of frail older patients as a complex health care intervention

The aging population is a challenge to the health care system. Indeed, a growing proportion of elderly people develop frailty syndrome, an independent predictive factor for incidental falls and worsening disability, hospitalization and death [1]. As a consequence, they experience functional decline requiring assistance for most day-to-day activities. This is usually provided by multiple-care providers, including relatives, raising the issue of coordination among them as a means to cover the needs and respond to the demands of frail older patients.

The Belgian federal government and its National Institute for Health and Disability Insurance (NIHDI) recognized the priority of this challenge. Indeed, NIHDI financed 21 'case management' pilot projects to decrease the risk of institutionalization of frail older people. Case management is defined as 'a collaborative process of assessment, planning, facilitation and advocacy for options and services to meet an individual's health needs through communication and available resources to promote quality cost-effective outcomes' [2]. Promising case management project designs may obtain structural financing in the future, provided a positive scientific evaluation. To this end, a qualified and technical health care management consortium provided an appraisal of these projects.

However, the evaluation and modelling of such interventions are hampered in many ways. Indeed, preliminary analyses show that the projects achieved heterogeneous levels of implementation in regard to their pre-set goals. The projects were also embedded within diverse local health care systems, accounting for a variety of partners and financing structures. In addition, these interventions also involve a large variety of actors, ranging from patients to informal and formal care providers. The project organization has to account for their disparate perspectives and human behaviours.

Hence, these projects adopted different organizational features, emerging from their local context. This underlying adaptive characteristic is common among complex health care interventions. These are often characterized by complex mechanisms such as feedback loops between the actors, delay effects and non-linearity [3]. These effects cannot be modelled properly by linear quantitative tools, leading to inconclusive results when assessed with classical effectiveness studies such as simple randomized control trial designs [4,5].

For these reasons, complex health care interventions are also studied with a qualitative approach providing a greater explorative power. Indeed, qualitative studies build on perceptions and interpretations to find a contextual meaning and propose a causation mechanism [6]. However, the mere fact that qualitative data are highly context-sensitive brings specific challenges regarding the generalization of findings.

Computer simulation for experts' elicitation

Knowledge elicited from field experts can prove to be a valuable source of qualitative information when data are scarce and context-sensitive. Indeed, this type of narrative method can shed light upon the complex causal mechanisms underlying the expected success of case management projects. However, such knowledge might still be hard to make explicit, and substantial know-how might remain tacit [7,8].

Computer modelling and simulation have been argued to provide one possible solution to overcome the complex aspects of health care studies, and articulate qualitative information [9–11]. More particularly, computer simulation can also be used as a tool for eliciting experts' opinions [12].

Indeed, experts' knowledge can be gathered, confronted and aggregated using a simulation model, by involving experts in a discussion to define problems and design possible solutions [13]. This model represents a formalized and generalized set of knowledge and assumptions.

Further use of simulation to evaluate health care interventions may be encouraged by successful accomplishments in other domains.

First, in the field of project management, simulation models have already helped managers to take steps forward in more informed decision-making processes and cost planning, by modelling multiple workers with highly diverse profiles within teams [14–16].

Second, simulation can also assist efficient organizational modelling and change management initiatives within companies. Building a simulation model, through a participatory process involving field actors and stakeholders, has already provided an articulation of the internal functioning of an organization, thereby revealing hidden assumptions, unstated procedures, and unwritten rules of practice [17].

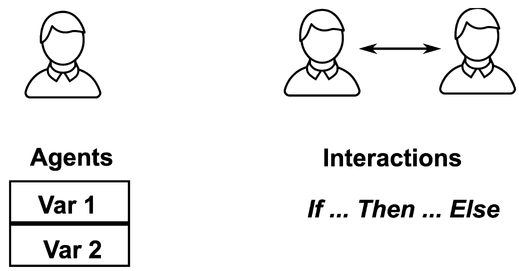

Figure 1 Agent-based methodology.

Third, the analysis of public policy modelling using multiple scenarios enabled more robust solutions by considering policy decisions as an adaptive response that evolves over time [18].

Finally, applications in ecology have also been designed using role-playing games supported by computer simulations. This type of methodology, called companion modelling, has already enabled to visualize and understand the interactions between human and natural systems. This process has already guided local population conciliation and helped to resolve resource allocation problems [13,19–21].

All of these applications typically use an agent-based model (ABM), which can similarly be used to assess the complex mechanisms underlying health care interventions. The ABM consists of the definition of an agent as a set of variables; several types of agents can be created and their rules of interactions defined [22,23] (Fig. 1). These rules of interaction can be expressed using a logical language such as If-Then-Else statements, which are well suited to capturing experts' opinions. Moreover, random effects can be introduced, and parametric analyses performed with a view to testing the validity of the model and its simulation results. Thanks to this flexibility, numerous scenarios can be designed.

In this paper, an ABM is built based on qualitative data extracted from 21 pilot case management projects. This model is then used as a support for the elicitation of experts to articulate formally the description of the intervention and the problems encountered. The objective is to improve the understanding of case management as a complex intervention.

Methodology

This study was implemented through four main steps (Fig. 2): (1) gathering empirical data from the 21 pilot case management projects; (2) building a conceptual framework; (3) designing a model and simulation plan; and (4) discussion with the experts.

Gathering of data from case management pilot projects

The 21 case management interventions financed as pilot projects by the NIHDI each had to provide information regarding the content of the intervention, its expected results on frail older persons' health states, and changes in those states occurring over time. Several sources of empirical data were available for each project: (1) an initial project submission file was used to conceptualize the key characteristics of the intervention and their expected impact on frail older people; (2) a yearly questionnaire

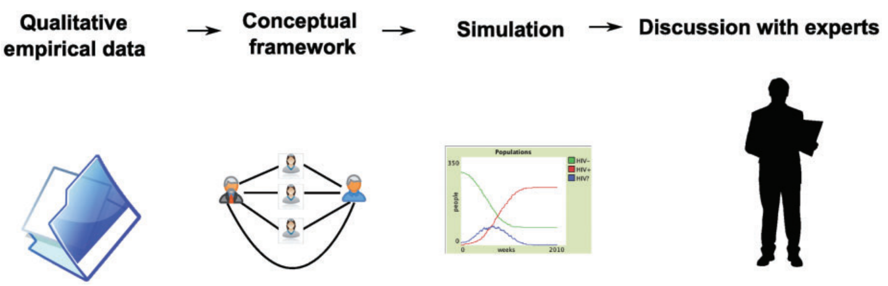

Figure 2 Simulation design leading to field experts' elicitation.

was used to assess the evolution of the project; and (3) researchers conducted specific case study analyses for 5 out of 21 case management projects to develop an in-depth understanding of the implementation process.

Conceptual framework

Based on a preliminary analysis of the empirical qualitative data, a simple conceptual framework was built following an agent-based methodology to describe the theoretical mechanisms at play in a typical case management project.

Agents and variables

Three agents were defined succinctly with a corresponding set of variables (Fig. 3).

- frail older person (FOP): needs and demands;
- care provider (CP): capacity; and
- case manager (CM): informal knowledge and organizational skills.

Following this typology, the qualitative material has been further analysed in order to provide an explicit definition for each variable. Even if these definitions and language elaborated could not be exhaustive, this ontological step revealed an essential common dictionary in further discussion with the experts. In addition, it clarified the description of case management in terms of operationalization.

Topology

Information about the empirical network topology, linking all actors involved in the projects was scarce. For illustrative purposes, the topology was implemented as represented in Fig. 4. Loops and delay effects can emerge from the chains of consecutive interactions.

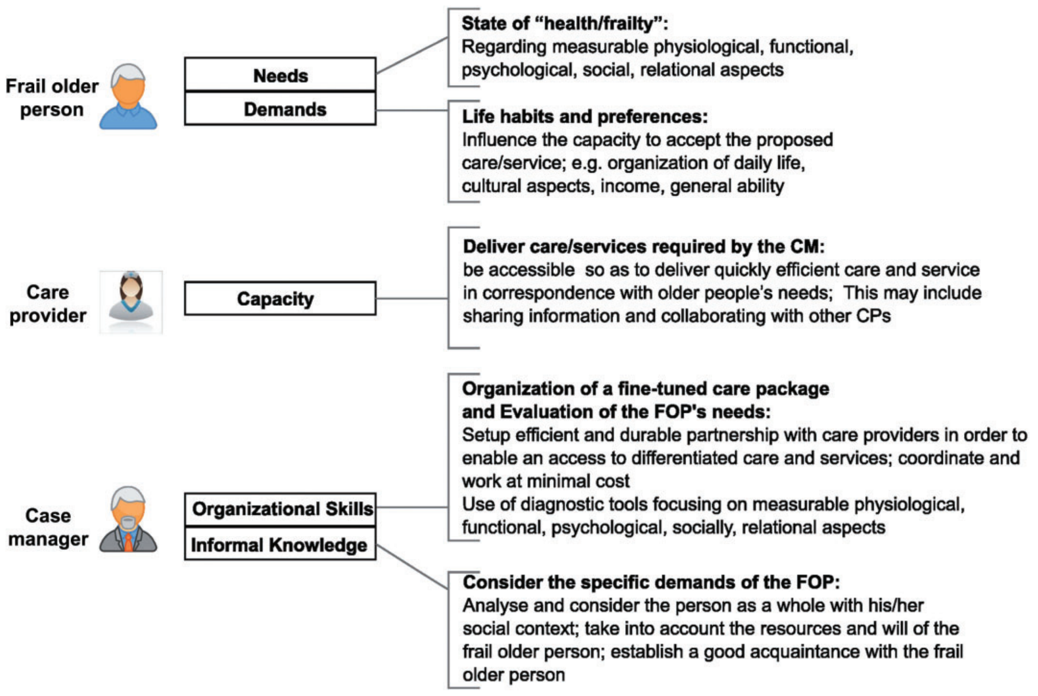

Figure 3 Three types of agents and ontological dictionary. Three types of agents are presented as a set of variables: case manager (CM), care provider (CP), frail older person (FOP). An ontological dictionary issued from the qualitative material is associated.

Interactions

Simple rules of interaction were designed and represented in a decision tree (Fig. 5). Each rule could be justified either relying on advocated common sense, either being supported by initial qualitative material or references from literature (see Supporting Information Appendix S1).

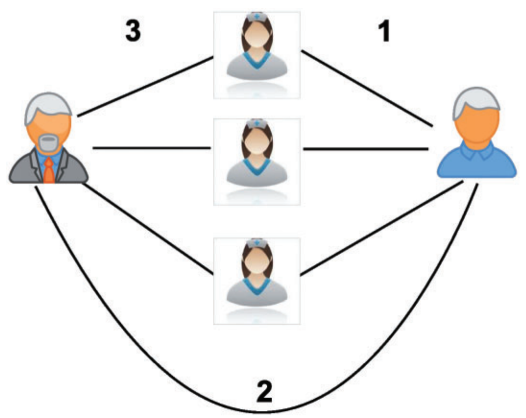

Figure 4 Exemplative topology representing the linkage between the three types of agents. This network topology represent the case management of one frail older person (FOP) and its interactions with its case manager (CM) the different care providers (CPs) involved in its care plan: (1) CPs-FOP; (2) CM-FOP: (3) CM-CPs.

Simulation

The model was implemented in Netlogo, a free open-source software package providing a user-friendly graphical interface (source code and installation details are available at the following link https://sourceforge.net/projects/cmpartsim/).

The conceptual framework was implemented so as to represent a virtual population of agents acting following the mechanism induced by the decision tree (Fig. 5; see Appendices 1 and 2).

The parameters that were used for the discussion are:

- the number of agents of each type (FOP, CP, CM);
- the initial levels of each variable of each agent, with the possibility to create random values for each agent's variable, so as to include unpredictable behaviours;
- the minimal numbers of links connecting CPs to FOPs and FOPs to CPs;
- the number of iterations the process is repeated;
- the adequacy cut-of-points above which demands are considered inadequate; organizational skills and informal knowledge adequate; and
- the incremental/decremental values to possibly modify the extent of the increase/decrease of the variables.

Following the selected values of the parameters, a population can be set up with the defined characteristics and linked within the

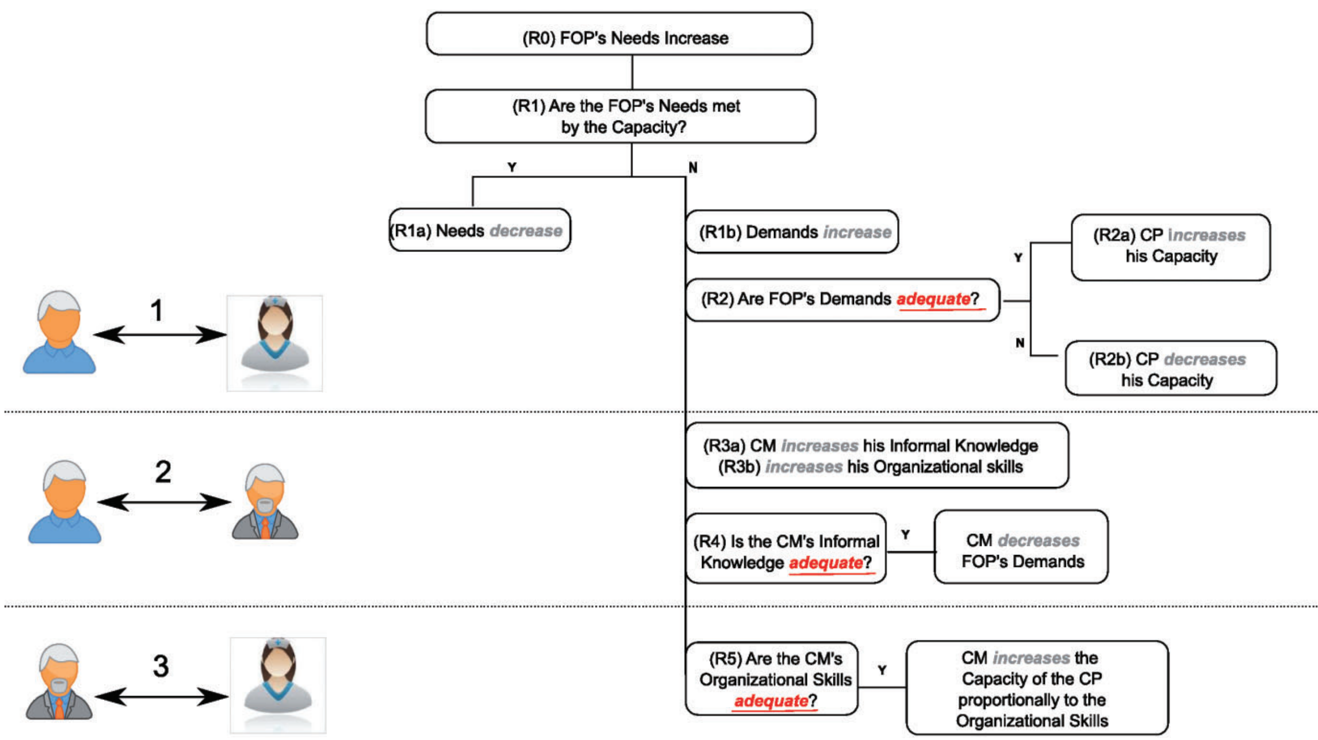

Figure 5 Decision tree. Decision tree describing the interactions between: the frail older persons (FOPs), their case manager (CM) and the different care providers (CPs) involved in the care plan. Two types of parameters can be set up to modify these rules. The adequacy cut-of-points above which Demands are considered inadequate; Organizational Skills and Informal Knowledge adequate. The increment/decrement parameters (gray) indicate the extent of increase/decrease of the variables.

desired network topology. The interactions between FOPs, CPs and CMs can be fine-tuned through the adequacy parameters and increment/decrement parameters in order to create diverse adaptation scenarios. During the simulation, graphs of the mean evolution of the agents' variables are plotted in real time.

Discussing the model and simulation with experts

This implementation was designed and presented to four experts in frail older people case management during a 3-hour workshop. Three of the experts (1 nurse and 2 social workers) were operational managers of three pilot CM projects presenting diverse organizational characteristics and target populations. They had experience in the day-to-day reality of case management. The fourth expert was a researcher, who also had extended field experience as a nurse. She had also performed the analysis of the qualitative data that led to the conceptual framework and decision tree. Her expertise covered the organization of frail older people care. The workshop was animated by a programmer and a medical doctor. Both were acquainted with the technique of simulation. The entire discussion was recorded for further analysis.

The workshop was organized into the following consecutive steps. First, the agents and the ontology of their variables were presented to the experts (Fig. 3). Quite naturally, the simplistic and possibly controversial definitions of the variables were subject to discussion, refining the concepts behind the terms. For example, the experts would have exchanged the terms 'Demands' and 'Needs' or would have renamed the informal Demands as 'Preferences'. In the subsequent discussion, the terminology was then specified as 'Formal Needs' and 'Informal Demands'. Despite the possible lack of political correctness of the terms, the experts could accept and handle the meanings of the variables. Hence, the ontological step proved useful in order to conceptualize these soft concepts, providing a dictionary to provide words that could be operationalized dynamically.

Next, the experts were invited to define their own projects within the conceptual framework, in terms of the established variables. The experts were able to discuss, compare their projects, position themselves within the schema, and express their opinions about the different roles, profiles and missions of the CMs.

Then, the rules of interaction (Fig. 5) were presented and discussed. While, the formulation of the rules and their presentation as a decision tree appeared quite destabilizing, the experts could accept each rule taken separately.

Finally, a virtual population was reconstructed step-by-step, beginning with the FOPs only, and successively adding CPs and one CM. Different scenarios could be progressively investigated, modifying the numbers of agents of each type, the initial states of their variables and the adequacy parameters (see Verification and Scenarios in Supporting Information Appendix S2). The group of experts and the researchers discussed each scenario, showing the computer simulation in real time. Eventually, the experts were able to interpret simulations similar to the one in Fig. 6 as follows (their narrative observations are related to the corresponding rules R0-R5 of the decision tree in Fig. 5).

While the unmet Needs of the FOPs increase (R0), their Demands increase as well (R1b). At the same time, the Informal

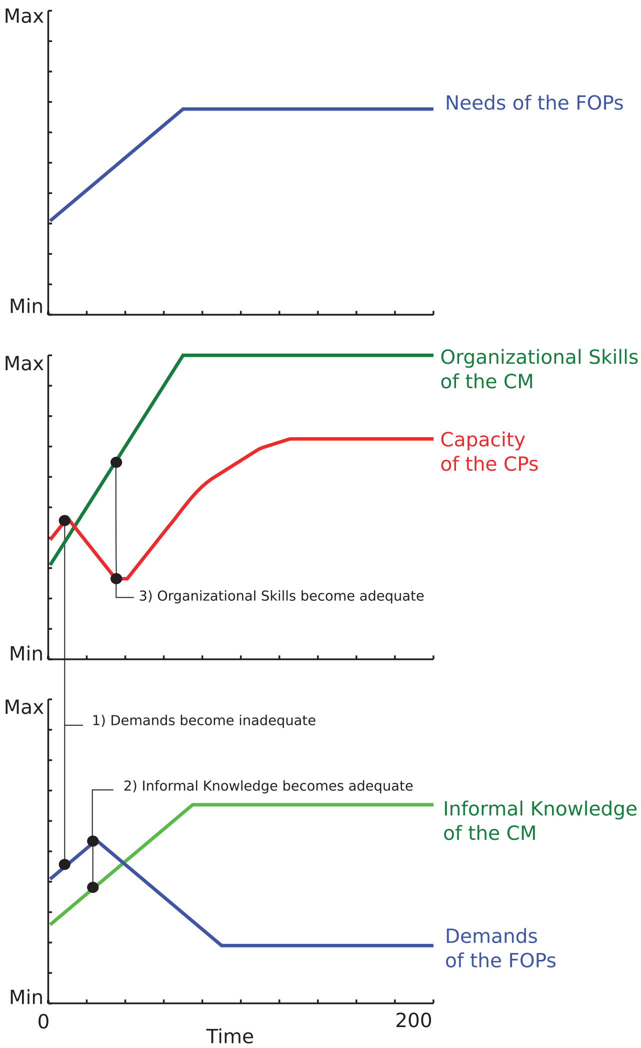

Figure 6 Illustrative output of the simulation model. Evolutions of the variables of frail older persons (FOPs), care providers (CPs) and case manager (CM).

Knowledge and Organizational Skills of the CM increase as well, indicating that the CM gains progressively better Informal Knowledge and adapts his or hers Organizational Skills (R3a-R3b). The CPs first adapt their Capacity (R2a), but when the FOP's Demands become too high (inadequate), the CPs decrease their Capacity, indicating that they cannot cope anymore (R2b).

The dynamic changes when the Organizational Skills and Informal Knowledge of the CM become adequate. First the CM is able to increase the Capacity of the CPs by improving the organization and the adequacy of the care (R5). Then the CM can also decrease the Demands of the FOPs (R4). This results in a stabilization of the Needs of the FOPs (R1a).

Ethical issues

According to Belgian law (Royal Decree 18, May 2004), Helsinki's Declaration (1964) and subsequent international regulations regarding human experimentation, Ethics' Committee agreement

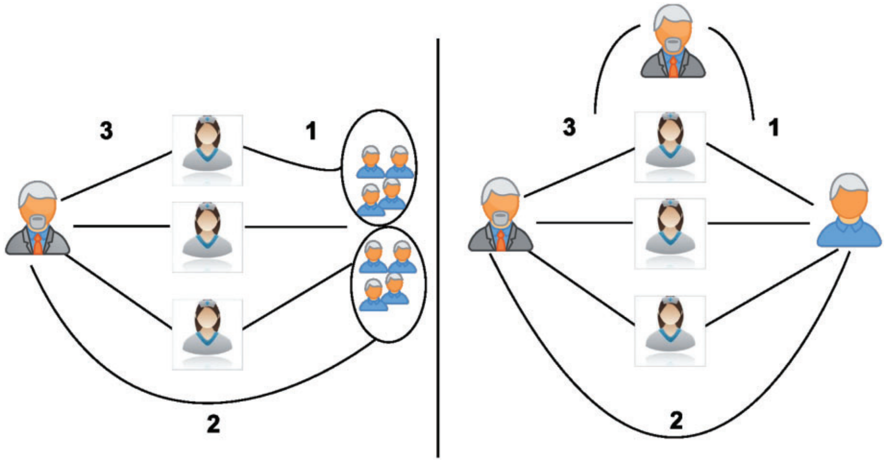

Figure 7 Different topologies as described by the experts. The case management projects presenting the topologies described by the experts, linking frail older persons (FOPs), their case manager (CM) and the different care providers (CPs) involved in the care plan: (1) CPs-FOP; (2) CM-FOP: (3) CM-CPs

was not required in order to conduct this study, as the research was not an intervention trial and did not involve patients. Expert professionals participating in this research were informed about the process and implications of their involvement and agreed to participate. They were aware that the data could be used for publication. Moreover, collected data were anonymized and every precaution was taken to make the data unidentifiable.

Results

In this section, the points discussed with the experts are formalized and classified by topics that hint at possible recommendations.

Project topologies

The experts were asked to define their project using the dictionary and the conceptual framework. Surprising differences emerged. For example (Fig. 7), one expert described the agent FOP as being a group of elderly people because the project was carried out in a shared housing environment. In this case, care was organized specifically using group dynamics between the elderly.

Another expert positioned himself higher than the CM; his role was not only to assess the Needs of the FOP but also the Needs of the networks of CPs around this person. One expert also spontaneously declared, 'this exercise allows a definition of factors and characteristics which look similar through projects, but that are actually totally different'.

Adaptation time

Through all simulations, the experts noted that a state of equilibrium in the different variables was reached after a lapse of time (Fig. 6). While this is in fact a numerical property of the simulation, the experts interpreted this as the adaptation time required for the CM to become acquainted with the elderly patient, the dedicated CPs and the local context in which the case management takes place.

Hence, an efficient initial assessment of the Needs may help CMs to decrease the period of adaptation when attempting to organize the care plan [24]. This critical phase could usefully enrol CPs or existing structure already acquainted with the FOP prior to case management interventions.

In addition, the experts expressed that it is better to have shorter visits with reduced length of case management, but increased frequency of visits for both CP and CM. While this intuitively allows for the monitoring of potential random accidents, it also contributes better to the understanding of the Demands of the FOP.

Information flow

While defining an ideal case management, the information flow between the different actors appears to be a crucial success factor, as rapid and efficient communication ultimately leads to better decision in critical cases [25].

The experts defined the ideal situation as being a setup where there would be no need for a CM. Hence, the experts noted that both roles of CP and CM could actually be acted in one person. Only the flow of information is modulated, regarding the FOPs' health state and their care plan. This was formulated by one of the experts, referring to the conceptual framework (Fig. 4): 'Somehow, Interaction 2 is the same as Interaction 1, only modulated by Interaction 3.'

Another solution could be a multidisciplinary team of CPs performing case management via intercommunication and meetings empowered by information technologies, as already encouraged elsewhere [26,27]. In fact, the implementation of software adequately dispatching information seems to have been the innovative focus of some projects, and to have been requested by others to enhance their daily organization.

Institutional context

Experts also expressed that the institutional context (political and financial) was responsible for the creation of obliged topologies and profile distributions between CMs and CPs, which were not always optimal. This might result from the Belgian-specific partition of competencies among different authorities.

More specifically, the coordination (one aspect of Organizational Skills) financed through regional budgets may not always

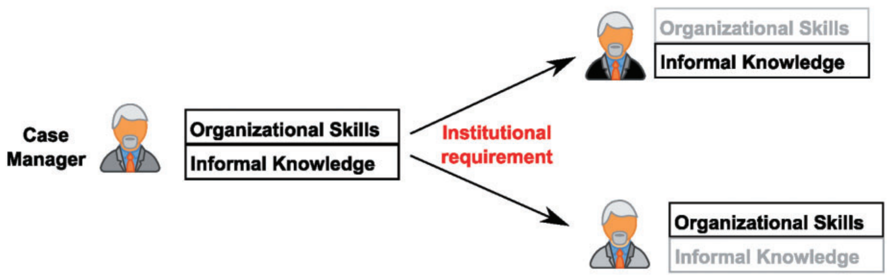

Figure 8 Institutional context requirement. Institutional context forces a separation of competencies of the case managers.

be combined with the health care functions (central to allow Informal Knowledge) financed through the federal budget. Therefore, the tendency may be to divide these functions between different persons to comply with this institutional requirement (Fig. 8). This impediment was qualified as a 'real brake for an efficient mission of case management'.

Hence, a clarification and a harmonization of the institutional context would benefit all actors of the system. One of the experts reported that, ideally, the task and function of the CM should include a good comprehension of the political and financial context in order to 'free' the CP from those institutional constraints.

Organization of care

Some simulated patterns presented uncontrolled increasing Needs of older persons. While adjusting the parameters, some adaptation processes were described as experienced in the projects. Some projects decreased the size of the targeted population while others added supplementary CPs to fulfil the Needs of the population. One project created a specific categorization between older persons with urgent needs and those persons requiring less attention.

Skills and role of the case manager

While the modelling of soft variables such as Informal Knowledge of the CM appears unusual, the experts confirmed and supported its crucial role in interpreting and addressing Demands of FOPS. They could report true cases where a wrong interpretation had led to an inadequate care plan.

For example, one expert reported the classic case of a woman who had called for assistance when she only needed company. Hence, experts emphasized that, for a CM, making the distinction between formal Needs assessment and Informal Knowledge to understand and interpret Demands was one big challenge in effective case management.

However they also pointed out that, in practice, CPs do also have Informal Knowledge to interpret Demands and to communicate their interpretations to the CM: 'The link CP-CM should compensate for the miss of the link CM-FOP' (see also Information Flow).

In addition, as a general comment, it appears that a precise description of the role of the CM should be formulated not to overlap missions of the CPs. While this definition needs to be clear, it should also reflect a contextual understanding of the responsibilities of the CMs, as already reported elsewhere [2]. Indeed, one specific ideal type of CM does not exist. A CM should be suited to the institutional context and take into account the capacities of each actor of the care plan. Hence, mandating too explicitly one ideal profile of the CM might be counterproductive.

Discussion

The development of an ABM to elicit experts' opinions was part of a valuable cognitive process shedding light on the usefulness of the reported insights. While this methodology should be seen primarily as a tool for thinking and learning [28], its validation and limitations needs to be addressed.

A valuable cognitive process

Several aspects of the methodology contributed to a valuable cognitive process for both researchers and field experts.

First, the conceptual framework expressed in terms of variables provided a vocabulary to properly elicit rules of dynamic interaction. The use of a formal language forced a non-ambiguous formulation of the rules and a clarification of the contextual effects.

Second, this formalism and the flexibility of ABM made it a powerful tool of communication between experts, providing an interactive medium for social exploration [11]. The informative interaction between modellers and experts allowed for improving and learning from the elicitation. In addition, while the experts might already have the right knowledge, the simulation could help them to phrase or adjust their internal representation. Better understanding and good communication skills can only improve their ability to manage and advise other stakeholders [29].

Finally, the resulting discussion was also beneficial to the experts to improve their practice. Indeed, the output of a simulation acted as a brainteaser for the experts' reasoning. Hence, from the simulated graph, a question emerged. A possible answer was then formulated, triggering a reinterpretation, and finally the experts associated the resulting dynamics to a case story of their own experience. This shared narrative contextualization was part of a collective sense-making exercise that challenged experts' belief through the discussion [30]. Hence, this cognitive scheme enhanced the expert's internal representation of the mechanisms underlying the interventions and ultimately prepared them to better adapt to unpredictable situations with creative solutions [31].

Usefulness of the reported insights

The insights that emerged from the experts' elicitation might appear obvious. However, they can become obvious only once they are formulated. The methodology used in this paper provided a medium to articulate a proper formulation of complex dynamic interactions [11,17].

Moreover, the enumeration of such insights, albeit obvious, may yet lead to necessary recommendations that need to be addressed. Hence, the simulation model provided a structure for a systematic inventory of these insights, which is a valuable step in a decision-making process [32].

In addition, personal internal representations and experience might lead to different interpretations of these insights. The discussion supported by the model's formalism ensured that each participant understood everyone else's interpretations, eventually resulting in better generic formulations.

Finally, the possible recommendations resulting from this type of exercise will likely have a strong advantage when it comes to field integration. Indeed, policies imposed from authorities may lead to failure because of a perceived or a real gap with the field [33]. Instead, the consultation of field experts and the resulting refinement aim at better generalizing their knowledge and experience as anchored in their day-to-day reality. Hence, such guidelines issued from a bottom-up approach may trigger a peer effect, facilitating their acceptance and implementation.

Validation

The stated purpose of the simulation model was to provide a tool for thinking and discussion with the experts. In this context, some have argued that it does not matter if the simulation is not connected to evidence [28]. However, an empirical grounding was initiated with serendipitous consequences.

First, the ontological step anchored in empirical data resulted in a real dictionary, so that confusion between different interpretations of variables could be resolved, in order to orient the debate. This grounding aligns the model with reality, and adds credibility to the model when discussing it.

Second, in the step-by-step reconstruction of the model, each rule underwent a strenuous evaluation by the experts to assess its stand-alone mechanics (see Supporting Information Appendix S2). Not only does this assessment increase the reliability of the rules, but also the time to analyse each step contributes to structure and formalize the experts' representations.

These steps aim at an empirical adequacy, which is a condition to reach a plausible model [34]. Hence, while the validation of a model in a complex context is still under debate, a connection with real data and a consistence with field experience proved beneficial for the participative process.

Limitations

Several limitations impacted the effectiveness of the model and the participative discussion.

The workshop with the experts was limited in time. All possible scenarios could not be investigated during the meeting with the experts. However, open discussion was preferred even when digressing from the ongoing displayed simulation. This actually left room for narrative exploration to reveal important information not covered by the model such as the problem of the institutional context.

As mentioned, the simple structure implemented to link the different agents was probably too naive as the experts described very dissimilar topologies. Hence, a proper comparison between projects needs to consider the projects' topological specificities.

The details of implementation were not described during the meeting (see Supporting Information Appendix S2). Only the terms 'increase' and 'decrease' were used to focus quickly on the dynamics of the model, which is better-suited to reveal complex effects.

There was an inherent destabilizing feeling among experts when presenting the simulation model. In a sense, they felt uneasy with the oversimplification and the 'cliché' of mathematical logic and computer code being used to represent the complexities of their work. However, the natural, but formal language induced by the decision tree and the If-Then rules quickly freed them and left room for enthusiasm and imagination. In the future, as general computer literacy increases over time, a greater interest from experts can be anticipated.

In this sense, many other interactions or modifications of the conceptual framework were mentioned and the experts were found eager to formulate these changes. In fact, in an ideal setup, an iterative process should be considered over the entire methodology. Indeed, the experts should already be actively involved in the design of the conceptual framework. In a sense, this is the case, as other experts are the source of the data that has led to the building of the conceptual framework. Further meetings with the same experts should also be performed to discuss additional scenarios that could then be walked through with other experts to test the robustness of the conceptual framework and its informational content.

Further information regarding the turnover of the CPs and Older Persons are required to perform a real assessment of the evolution of the project. Indeed, this might be an important indicator regarding the adaptive patterns of the project, but it was not implemented in this exercise.

Given the diverse profiles and occupation of the experts, they all present different levels of both codified and tacit knowledge that could impact their responses throughout the elicitation process. While the methodology exercise provides one canvas for elicitation, some pieces of knowledge may still remain hard to make explicit.

Finally, the benefits to the learning process of the experts are neither immediate nor quantifiable [35]. As recommendations and rules might appear intuitive depending on a priori knowledge, the lessons learned might be different for every expert. While new simulations are drawn within seconds and interpreted without consequences, the actual enactment of lessons learned might require further confidence from the experts. In this context, concrete applications and benefits in real-life situations appear difficult to be accredited to the simulation exercise.

Perspectives

At this early stage of model building, the level of complexity remains limited. However, the current simulation model supported by the experts' comments can be seen as a strong foundation for future research and development [17].

First, the observation and remarks that emerged from experts' elicitation should be investigated and other scenarios implemented. For example, CMs and CPs could be removed from the system to simulate their absence/disappearance. These simulations and subsequent discussions of the results with the experts could provide an insight into the robustness of the solutions.

Second, this methodology and subsequent scenarios could be used to help to train care providers, case managers and other health care personnel by encouraging them to reflect on their own practice and better adapt to unexpected situations.

Third, while this study was focused on the action of one (or no) CM, the flexibility of the model allows scaling up to study several coexistent projects of case management sharing resources, via different project topologies.

Fourth, further questions should be investigated regarding economic and time resources. While this is not applied in this study, quantitative data could be used in the model. These could be used either as input, or as a comparative benchmark for the simulation to recreate real project case stories and evaluate their cost.

Finally, this type of exercise could usefully support the formulation of cooperative requirements of an integrated human–machine application for operational purposes [36]. However, much further work is needed in these areas to achieve operational efficiencies.

All these steps could lead to finer recommendations and issue better-informed decisions in the organization of frail elderly case management.

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Appendix S1. Rules and settings justification.
Appendix S2. Technical Guide.